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Title: From Manhattan to Mars: Applying models of subsurface radionuclide gas seepage from nuclear testing to understand methane release from the Martian subsurface

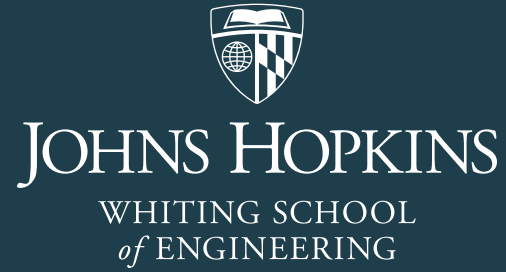
Author(s): Ortiz, John Philip
Rajaram, Harihar

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From Manhattan to Mars:

Applying models of subsurface radionuclide gas seepage from nuclear testing to understand methane release from the Martian subsurface

John P. Ortiz

Advisor: Harihar Rajaram

Environmental Health & Engineering Seminar
2 November 2021

What is the → MARS METHANE MYSTERY



Summary of key methane measurements at Mars

ExoMars Trace Gas Orbiter
reports absence of methane,
with upper limit
of **0.05 ppbv**



2018

Curiosity's first four years
suggest seasonal background
variation of **0.2–0.7 ppbv**

2012–2018

2012–2014



Mars Express finds no
methane, except for one
15 ppbv spike one day
after **Curiosity** detection

2013

Curiosity measures a
methane spike of **6 ppbv**



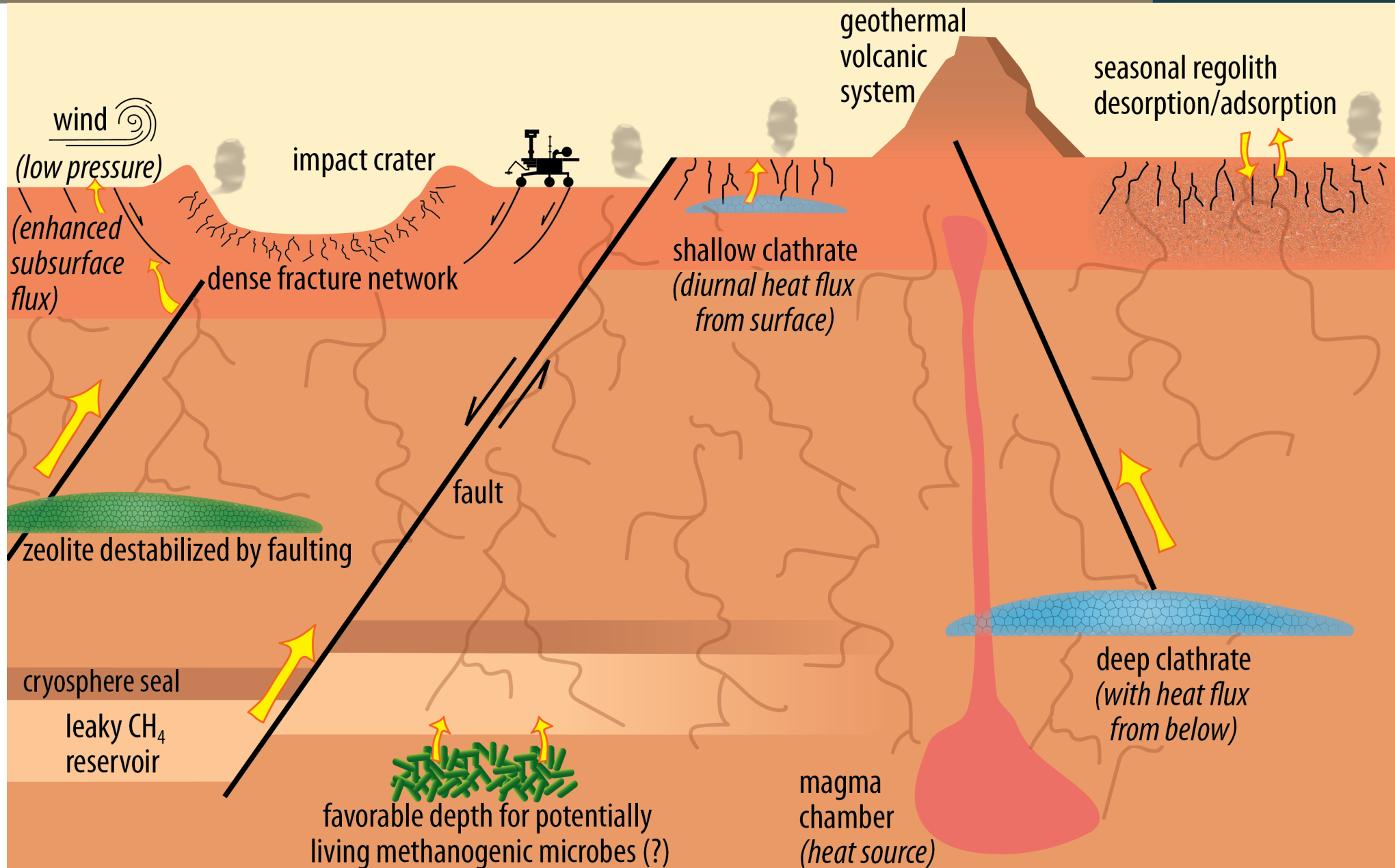
Early **ground-based** observations
indicate **10 ppbv**; later observations
report values up to **50 ppbv** in
extended plumes over specific regions

1999 / 2003

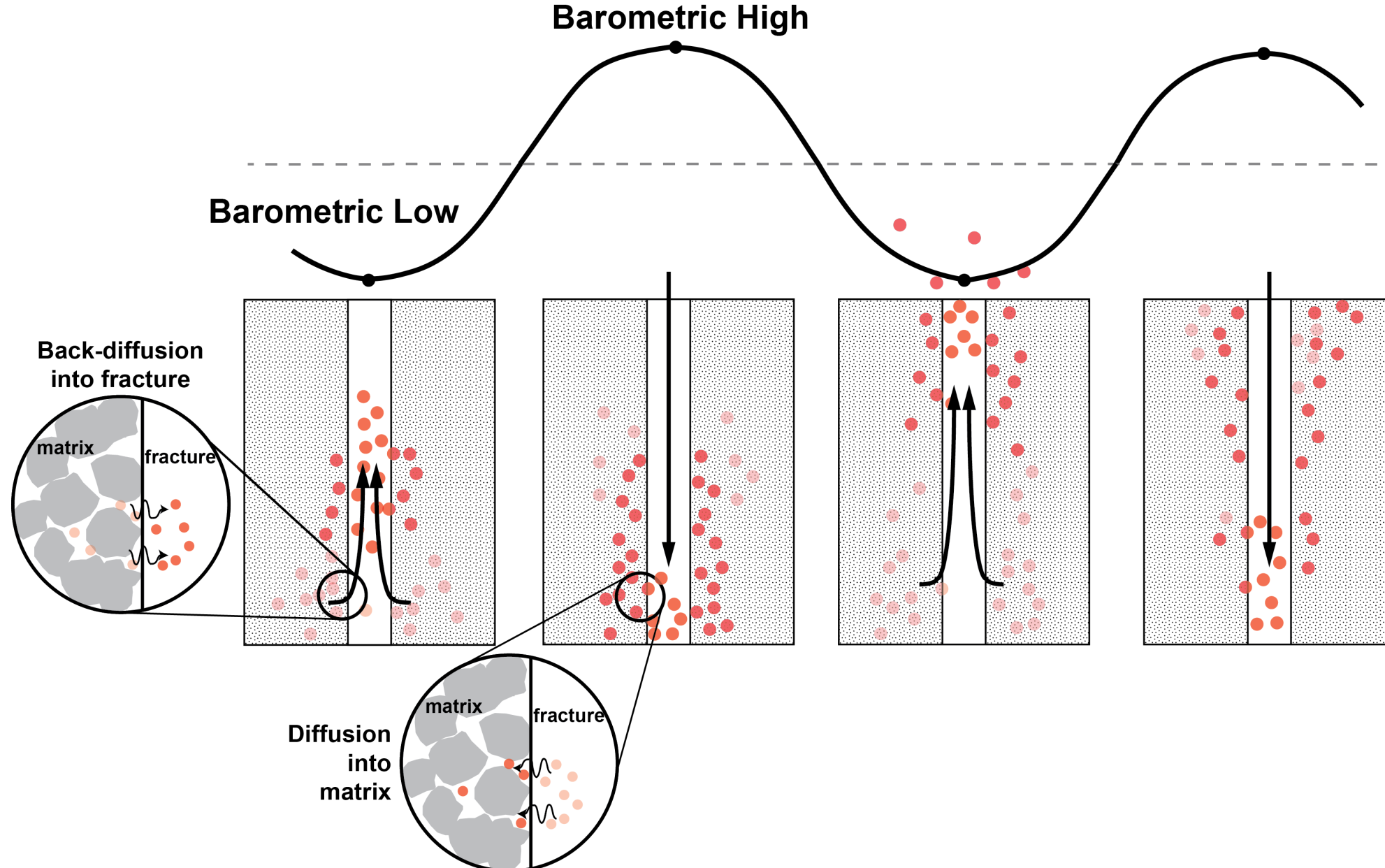
2004



Mars Express
early measurements
report variations of **0–30 ppbv**



On Earth, barometric pumping enhances subsurface transport



Mars has fractures!



Using entire frame:

total area: 251.531 cm²

fractures: 0.245 cm²

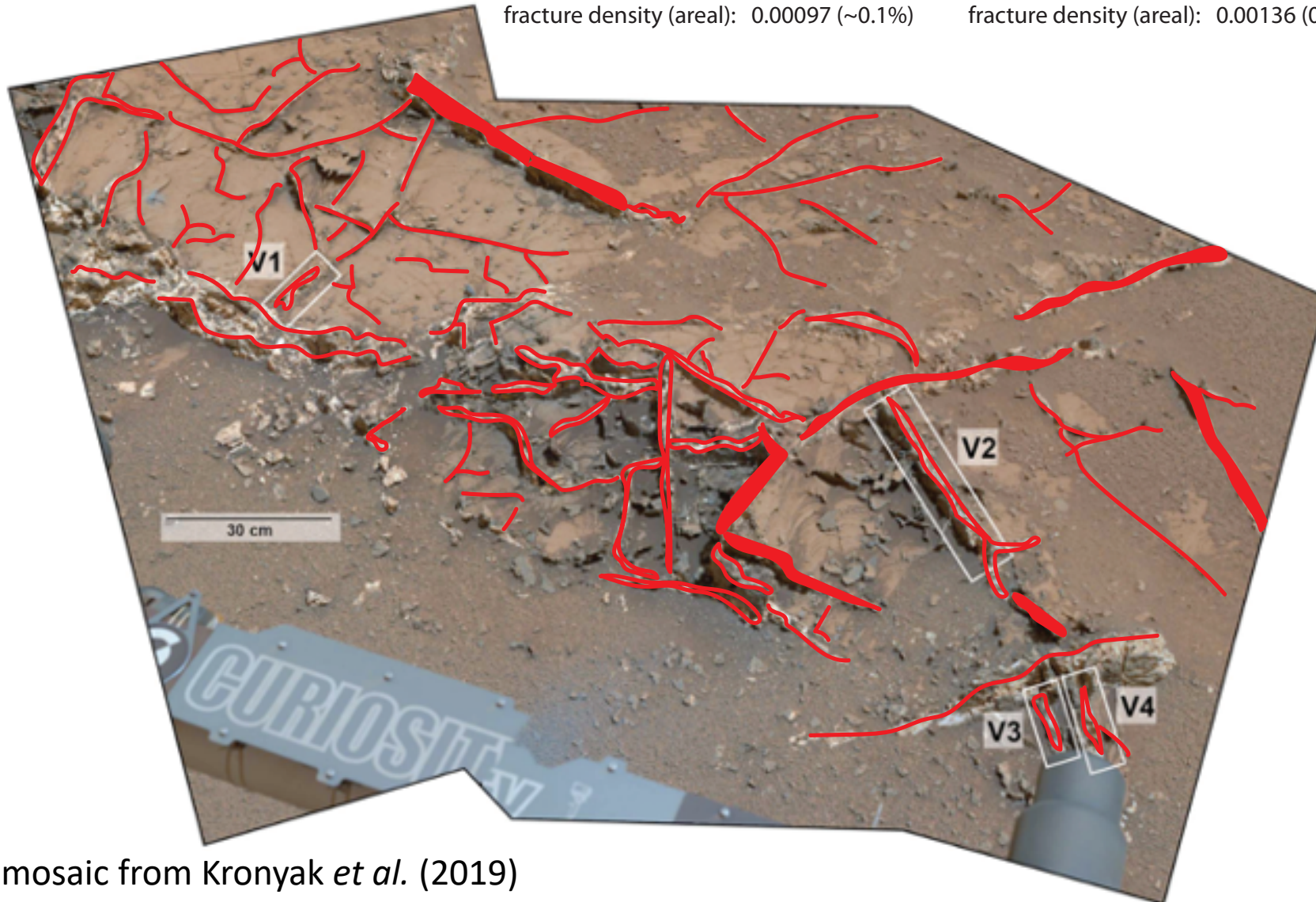
fracture density (areal): 0.00097 (~0.1%)

Using frame of just the fractured area:

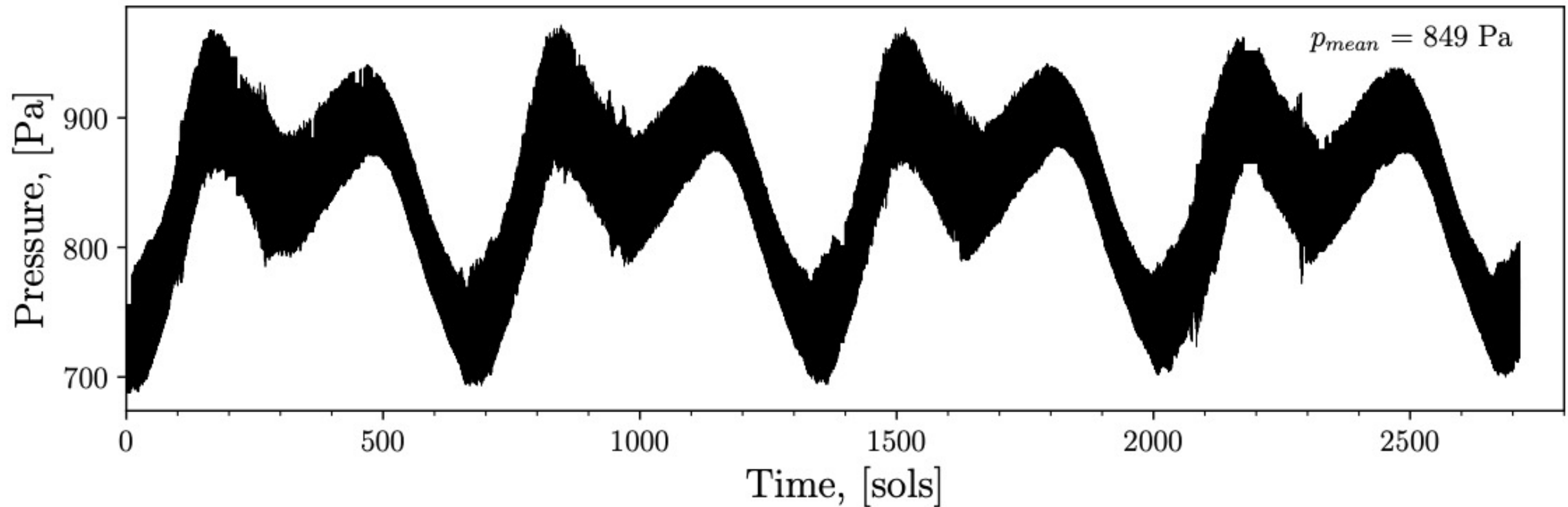
total area: 180.142 cm²

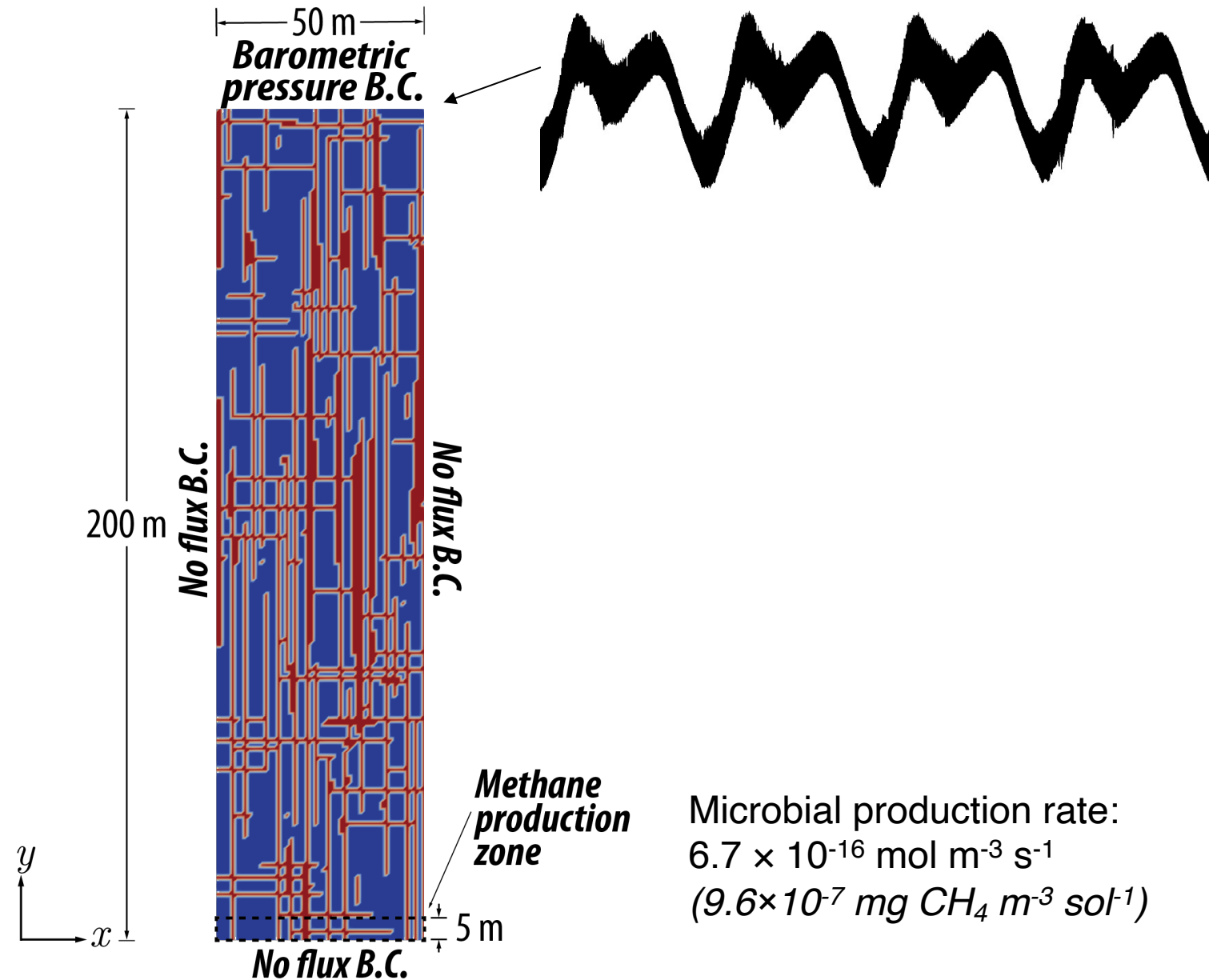
fractures: 0.245 cm²

fracture density (areal): 0.00136 (0.1%)

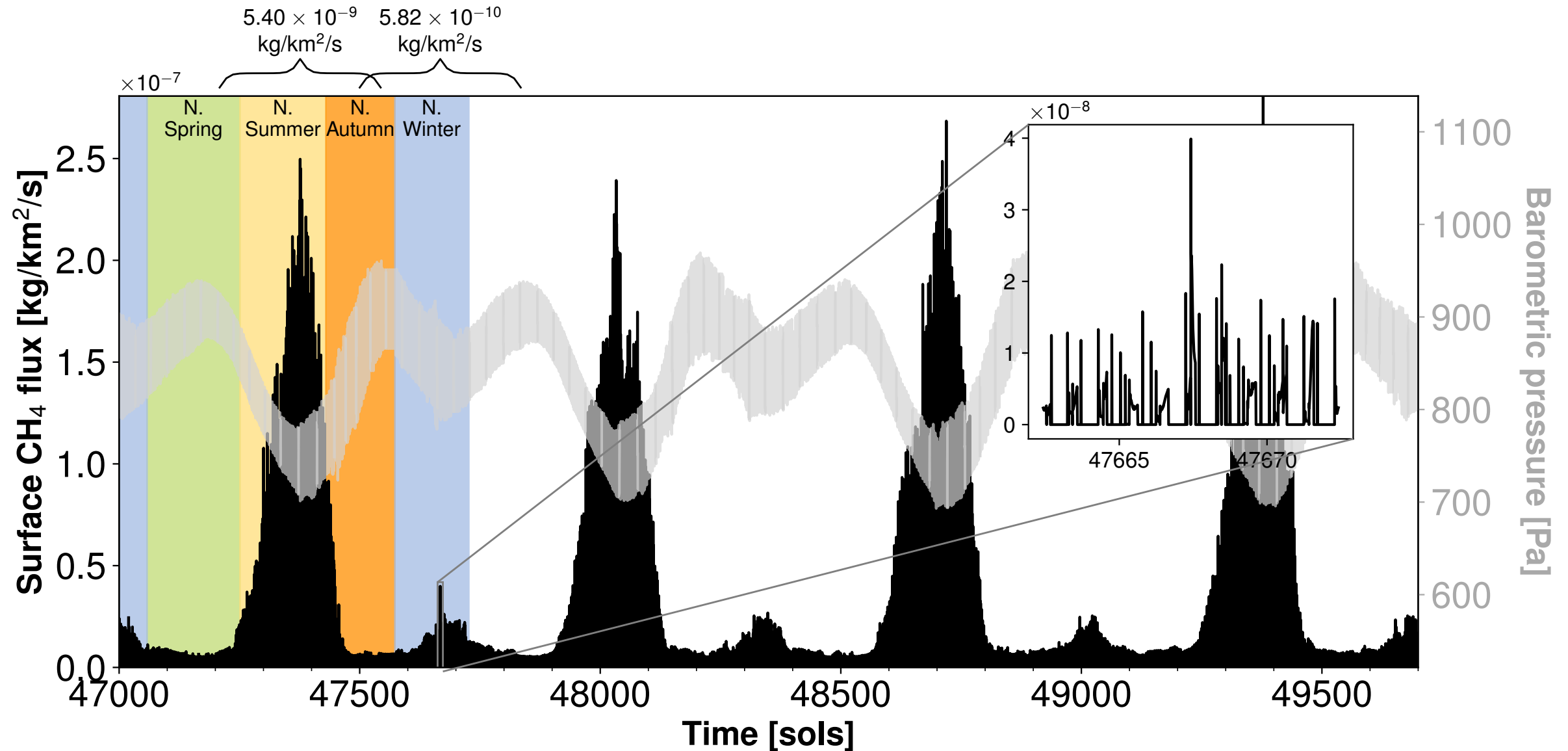


Mars also has barometric fluctuations!





Significant surface CH₄ flux at steady-state

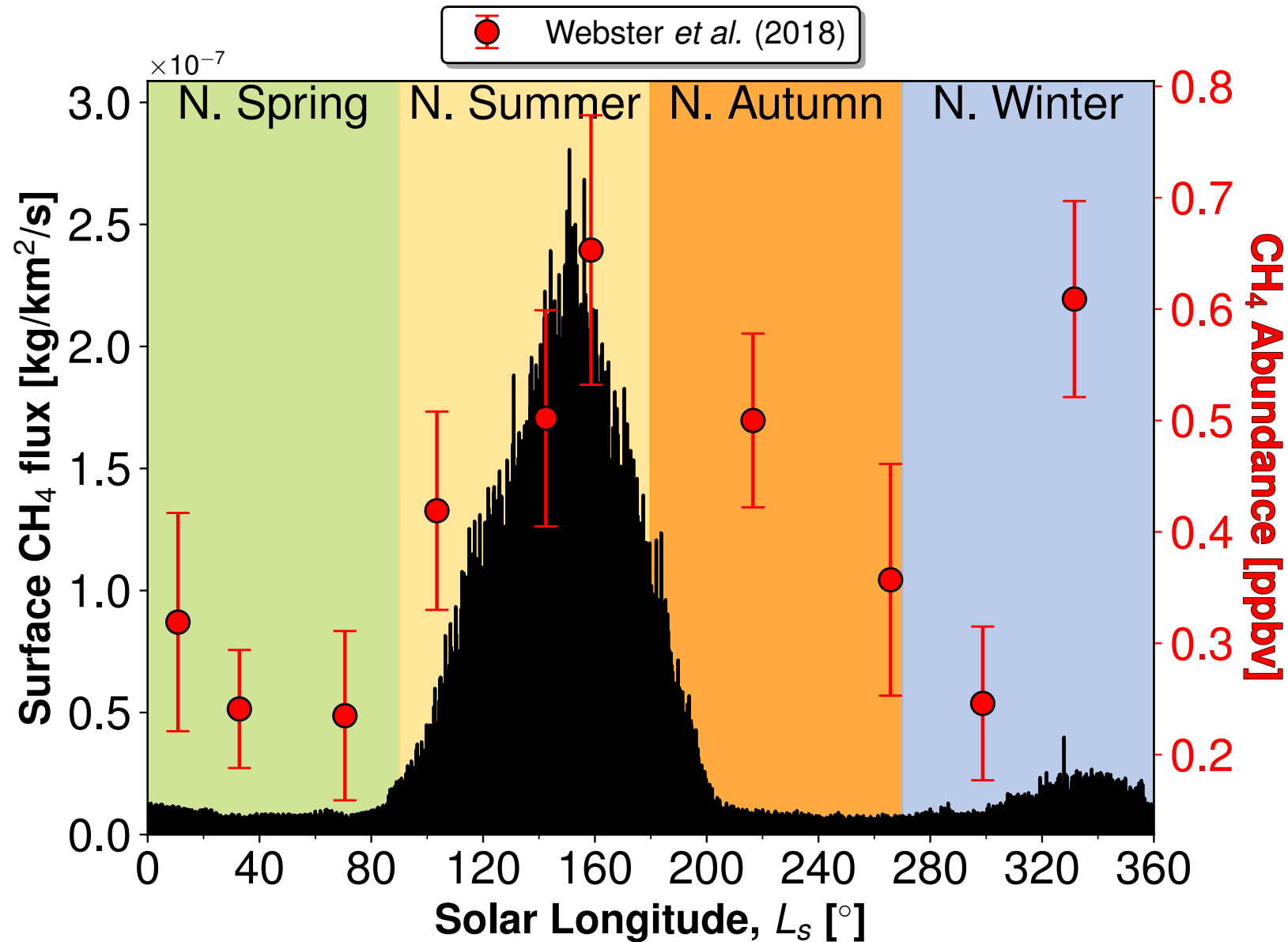


Case	Time-averaged flux $10^{-8} \text{ [kg} \cdot \text{km}^{-2} \cdot \text{s}^{-1}]$		
	Window duration		
	58 sols	117 sols	334 sols
base case	1.32	1.15	0.54
high k_m	1.26	1.12	0.57
low k_m	1.13	0.97	0.47
low ϕ_m	1.56	1.33	0.63
Moore, Gough, et al. (2019)			0.84*
Formisano et al. (2004)			0.002 [†]

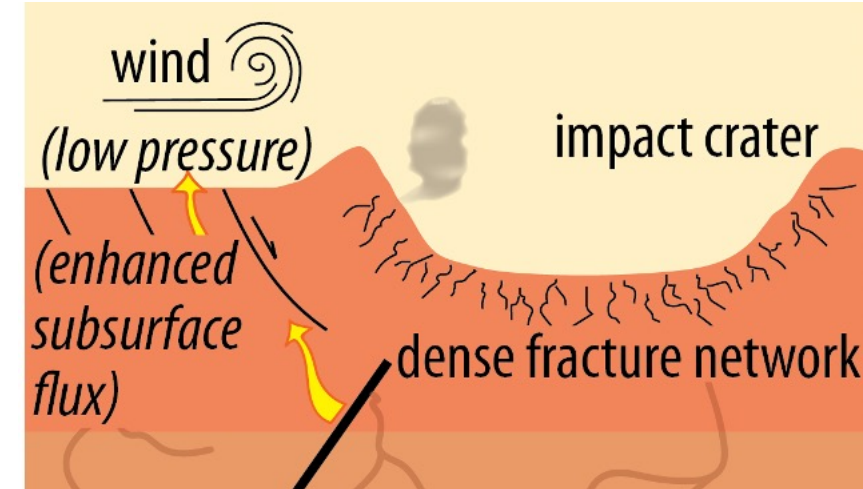
* Upper limit assuming seepage restricted to Gale Crater.

[†] Assuming continuous, uniform planet-wide seepage

Our fluxes reproduce seasonality of atmospheric abundance



- Investigate a wider range of methane release mechanisms
 - More advanced physics
- Develop a coupled atmosphere-subsurface model
 - Will allow us to investigate interaction between wind and topography (i.e. Bernoulli) →
 - Code will be made available as Open Source





JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Extra Slides









- Extension of dominant transport frequency to fracture *networks*
- Sorption processes
- Gas flow/transport in deformable fractures
- Subsurface gas flow/exchange on Mars